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Effect of Binders on Fastness Properties of Pigment Printing in Textile Fabrics

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The improving quality of chemical paste pigment prints was the main goal in product development. Afterwards the economic, environmental and toxicological considerations have become more important. Using more environmentally friendly pigment preparations and chemical auxiliary products, for example to reduce or to eliminate formaldehyde on the fabric, is currently one of the major concerns in the textile printing industry. The curable oligomers take the place of the organic solvents and work as the binder of pigments. Some novel prepared aqueous binder of polyurethane acrylate based on either polyethylene glycol or glycerol ethoxylate-co-propoxylate having zero volatile organic compounds was used for preparing printing paste for printing of all types of textile fabrics using pigment dyes. The highest colour strength is obtained and fastness properties range between good and excellent for samples printed using polyurethane acrylate based on glycerol ethoxylate-co-propoxylate as a binder, this is true irrespective of the type of fabric used. While lower value of colour strength is obtained for samples printed using Ebecryl 2002 as a commercial binder and polyurethane acrylate based on PEG2000 is better than polyurethane acrylate based on PEG1000 + 2000, unless in case of screen printed wool, the inverse is true.

Key Words: Improvement fastness, Binder's chemical structure, Pigment printing, Textile fabrics.

INTRODUCTION

Pigment textile printing is not only the oldest but also the easiest printing method as far as simplicity of application is concerned[1-5]. More than 80 % of the printed goods are based on pigment printing to its various advantages, such as versatility, ease of near final print at the printing stage itself, *etc*. This pigment printing makes use of mineral turpentine which is involved in making emulsion thickeners. In this system, the oil in the emulsion gets

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evaporated to the atmosphere at the time of curing of the pigment printed fabric[6]. It is almost impossible to reclaim this kerosene. In spite of the superior thickening properties of oil/water emulsion which also contribute towards a soft hand of the print, good fastness properties, ease of application methods and economy and several other factors have compelled the search for a replacement for oil; some of these are[6,7]: (i) The ongoing oil crisis, both in terms of cost and availability makes it imperative to minimize kerosene use. (ii) When printed fabrics are dried at 95-100 ºC and cured in ovens at 150 ºC, the surrounding atmosphere in the oven must contain enough excess of air volume in relation to the volatile hydrocarbon volume to ensure that the mixture is below the explosion point. A number of fatal accidents caused by explosions in curing ovens proved that this system is highly risky. (iii) The emission of high percentage of hydrocarbons through the curing exhausts is considered to be posing a serious problem.

The use of synthetic thickening agents and new developments in printing auxiliaries have also contributed to the increasing importance of pigment printing, since here, too, environmental aspects such as minimization of formaldehyde emissions and carbon dioxide content must be taken into account. At the same time, novel binder systems allow a much softer handle to be attained[7,8]. Formaldehyde emissions and clogging on the screens during the actual printing process must also be taken into account[9,10]. These disadvantages are related to the binders used.

The aim of this work was to examine some aqueous binders having low viscosity and zero volatile organic emissions of polyurethane acrylate based on either polyethylene glycol or glycerol ethoxylate-co-propoxylate in pigment printing and the new idea is not only fixation of the pigment dye through the polymerization process of the binder but also printing all types of fabrics using pigment dyes.

EXPERIMENTAL

Aqueous binders of polyurethane acrylate based on either polyethylene glycol 2000 and 2000 mixed with 1000 or glycerol ethoxylate-co-propoxylate had been prepared[11-14]. The commercial binder was supplied under the commercial name Ebecryl 2002 by UCb, Belgium. Acraconz BN (thickener synthetic) Bayer Co, Germany. Ammonium sulfate $(NH_4)_2SO_4$, MERCK, Germany. Desizing, scoured, bleached and mercerized wave cotton fabric (100 % cotton 130 g/m^2),viscose fabric [100 % viscose] of 130 g/m^2, wool fabric [100 % wool] of 140 g/m^2, polyamide fabric [100 % nylon 66] of 100 g/m^2 and polyester fabric [100 % PES] of 90 g/m^2 supplied by TexlabCo. Urea MERCK, Germany. Emulsifier V02 Bayer Co, Germany. Acramin softener MPG Bayer Co, Germany.

The pigment printing pastes were prepared according to the following recipe:

Imperon (Pigment) dye	3-5 %
Acraconz BN	1-1.5 %
Binder	3-5 %
Ammonium sulfate	2 %
Urea	0.5 %
Acramin softener MPG	1.5-2 %
Distilled water Balance to	100 %

The binder used was either polyurethane acrylate based on polyethylene glycol.

Printing technique: The fabrics printing was carried out using screen printing machine, Type VP-AL-500, Germany, the printed fabrics were dried in air at 95-100 ºC. The goods were subjected to thermal treatment in a thermostatic oven (Mathis, Switzerland) to fixation at 150 ºC the colour through the polymerization process. After that the printed goods were subjected to washing at 45 ºC with 1 g/L soap (Diadavin EWN Bayer Co, Germany) rinsing thoroughly with cold water.

Testing and analysis: The rheological properties and apparent viscosity of the printing pastes were measured using fluids spectrometer RFS II (Rheometrics CO 1483), Germany at 25 ºC and at different shear rates.

Colour measurements: The relative colour strength of the prints, expressed as K/S value[15] of the printed samples was determined by reflection measurements using data colour international model SF 500, USA.

Fastness properties: Fastness to washing, rubbing and perspiration was assessed according to the standard (AATCC) methods[15-18].

RESULTS AND DISCUSSION

This work was carried out with the following three main objectives in mind: (i) Elimination of either oil/water emulsion or formaldehyde emissions in pigment printing by using some novel prepared binder containing unsaturation sites which is responsible for fixation of the pigment through polymerization process. (ii) Evaluation of the prepared binder[7-9] of polyurethane acrylate based on either ethylene glycol or glycerol ethoxylate-co-propoxylate as a binder used in preparation of printing paste. (iii) Printing of all types of fabrics using the pigment dye, through this new technique, which is dependent on the fixation of the dye through the polymerization process that happened to the binder used under the effect of the temperature of fixation.

Since the rheological properties of the printing pastes and their viscosity are responsible for controlling dye penetration, depth of shade, sharpness of the print and levelness, it is of great interest to investigate the rheological properties of the printing pastes.

The rheological properties and apparent viscosity of freshly prepared printing pastes using 1 % sodium alginate and 40 % of polyurethane acrylate based on either polyethylene glycol or glycerol ethoxylate-co-propoxylate and/or commercial binder Ebecryl 2002 on using 3 and/or 5 % Imperon Brilliant red B are shown in Figs. 1 and 2, respectively.

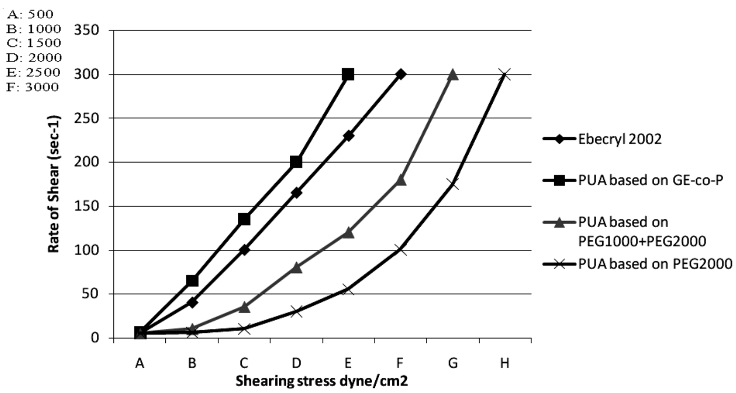

Fig. 1. Rheological properties of freshly prepared printing pastes using 1 % sodium alginate and 40 % of prepared binder of polyurethane acrylate based on either polyethylene glycol or glycerol ethoxylate-co-propoxylate (GE-co-P) and/or commercial binder Ebecryl 2002 on using 3 % Imperon Brilliant red B

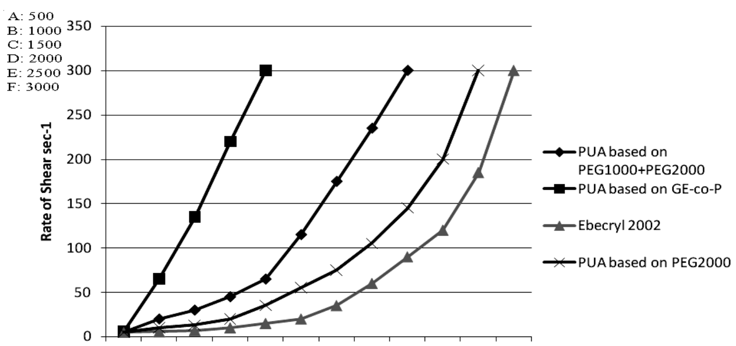

Fig. 2. Rheological properties of freshly prepared printing pastes using 1 % sodium alginate and 40 % of prepared binder of polyurethane acrylate based on either polyethylene glycol or glycerol ethoxylate-co-propoxylate (GE-co-P) and/or commercial binder Ebecryl 2002 on using 5 % Imperon Brilliant red B

It is clear from Figs. 1 and 2 that all samples examined were characterized by non-Newtonian pseudo plastic behaviour, where the up and down flow curves are coincident. It is also clear from Figs. 1 and 2 that the location of the rheogram and its slope seems to be dependent not only on the type of binder used but also on the concentration of dye used, which indicates a variation in the apparent viscosity. The rheogram curve of the commercial binder used (Ebecryl 2002 containing 3 % dye) was shifted nearest to the axis of the rate of shear indicating a decrease in its apparent viscosity as shown in Fig. 1, while on using 5 % dye, the rheogram curve was shifted far from the axis of the rate of shear indicating an increase in its apparent viscosity.

As shown in Fig. 2, but *vice-versa* in case of using the prepared binder of polyurethane acrylate based on either polyethylene glycol or glycerol ethoxylate-co-propoxylate. For example, at a rate of shear 10.0007 s^1, the apparent viscosity of Ebecryl 2002 increased from 2.19 to 5.303 Pas, while it decreased from 6.348, 4.757 and 1.593 to 3.984, 3.425and 1.327 Pas in case of using polyurethane acrylate based on PEG2000, PEG1000 + 2000 and GE-co-P, respectively, by increasing the amount of dye used from 3 to 5 %. This may be due to the difference in the chemical constituent of prepared binder and the commercial binder used, may be the dispersant medium of the pigment dye containing some groups which make cross-links or form hydrogen bonding with the Ebecryl 2002 which lead to an increase in its molecular weight and leads to increase in its viscosity.

Screen printed cotton and polyester fabrics: The effect of increasing the fixation temperature on the colour strength of screen printing on either cotton (natural fabric) or polyester (synthetic fabric) upon using Ebecryl 2002 as a commercial binder and/or prepared binders of polyurethane acrylate based on PEG2000, PEG1000 + PEG2000 and based on glycerol ethoxylate-co-propoxylate containing Imperon Brilliant red B of different concentrations 3 and 5 % and the time of fixation of 2 min are represented in Figs. 3-6, respectively. It is clear from the Figs. 3-6 that the colour strength of the printed fabrics (using either 3 or 5 % dye) is nearly comparable.This may be attributed to the increase in the dye concentration needed to increase in the binder concentration to make fixation to this dye through the polymerization process to this binder.

It is also clear from Figs. 3-6 that the highest colour strength values were obtained in case of using polyurethane acrylate based on glycerol ethoxylate-co-propoxylate [PUA based on GE-co-P] as a binder in the printing paste as compared to the results obtained upon using the commercial binder of Ebecryl 2002, which gives the lowest value of colour strength in case of screen printed cotton fabrics, while in case of using PUA based on PEG2000, the K/S values were better than the values obtained in case of using PUA based on PEG1000 + PEG2000. For example, the K/S values of screen

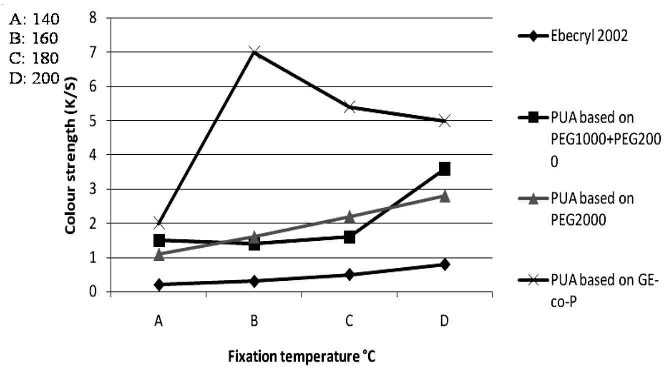

Fig. 3. Effect of the type of binder used on the colour strength of screen printed cotton fabrics using 3% Imperon Brilliant red B, the time of fixation is 2 min

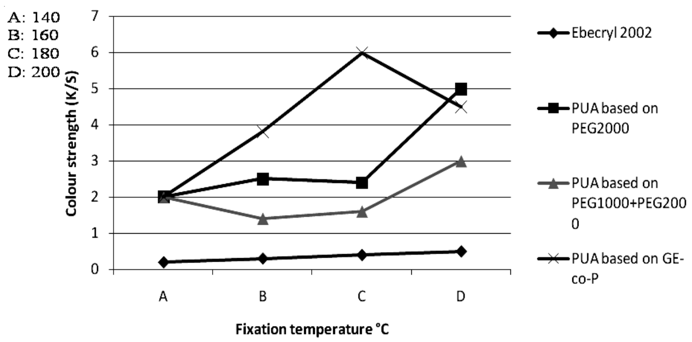

Fig. 4. Effect of the type of binder used on the colour strength of screen printed cotton fabrics using 5 % Imperon Brilliant red B, the time of fixation is 2 min

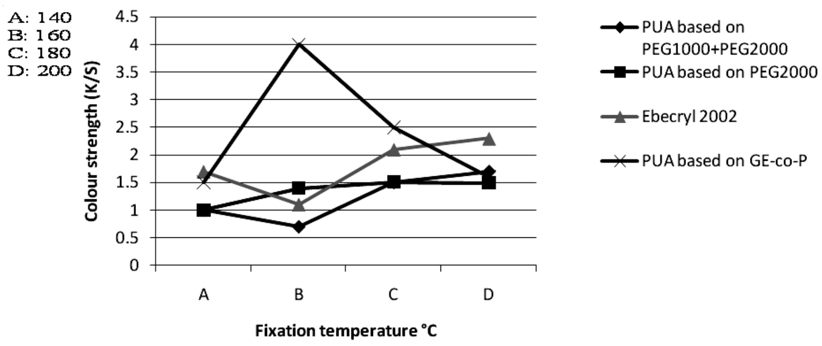

Fig. 5. Effect of the type of binder used on the colour strength of screen printed polyester fabrics using 3 % Imperon Brilliant red B, the time of fixation is 2 min

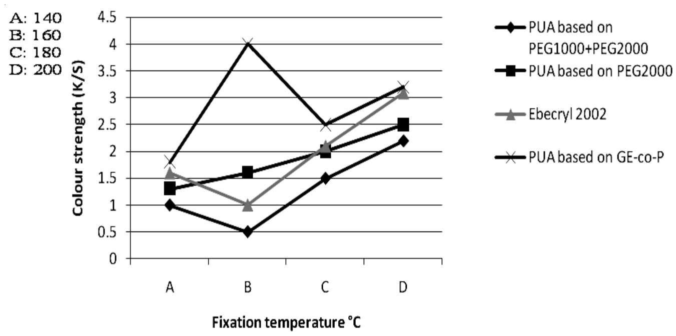

Fig. 6. Effect of the type of binder used on the colour strength of screen printed polyester fabrics using 5 % Imperon Brilliant red B, the time of fixation is 2 min

printed cotton and polyester fabrics fixed at temperature 16 ºC were 0.31, 1.9, 1.77, 6.83 and 0.85, 1.01, 0.65, 4.73 by using Ebecryl 2002, PUA based on PEG2000, PUA based on PEG1000 + PEG2000, PUA based on GE-co-Pas a binder in printing paste containing 3 % Imperon red B, respectively. This may be due to either the difference in the structure of the binder used or the amount of unsaturation groups found in the binders which is responsible for fixation of the dye through the polymerization process that happened to these oligomers *i.e.* binders.

Screen printed viscose, wool and nylon 66 fabrics: The effect of increasing the fixation temperature on the K/S of screen printed viscose, wool and nylon 66 fabrics upon using Ebecryl 2002 as a commercial binder and/or prepared binders of PUA based on PEG2000, PEG1000 + 2000 and based on GE-co-P containing 3 % of Imperon Brilliant red B, the time of fixation of 2 min are represented by Figs.7-9, respectively.

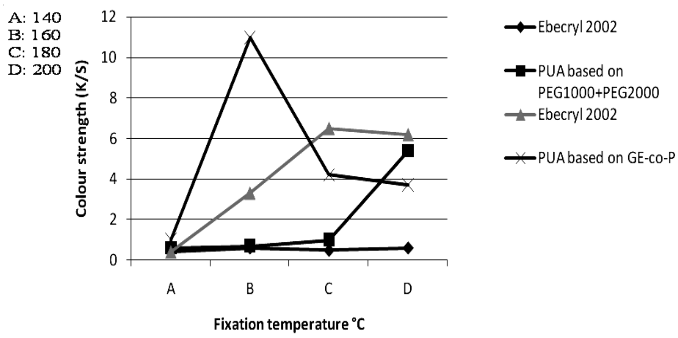

Fig. 7. Effect of the type of binder used on the colour strength of screen printed viscose fabrics using 3 % Imperon Brilliant red B, the time of fixation is 2 min

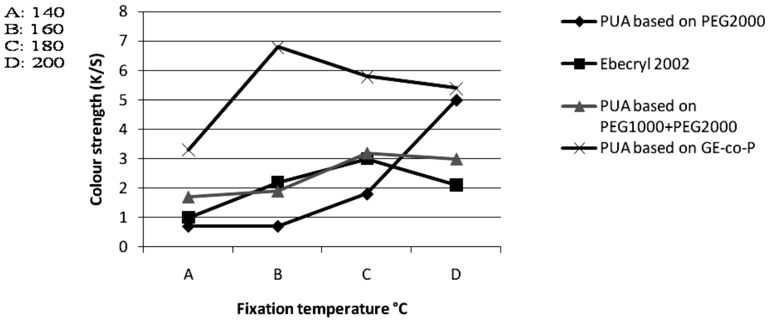

Fig. 8. Effect of the type of binder used on the colour strength of screen printed wool fabrics using 3 % Imperon Brilliant red B, the time of fixation is 2 min

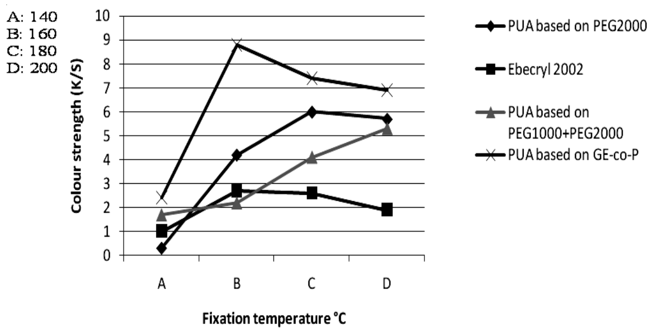

Fig. 9. Effect of the type of binder used on the colour strength of screen printed nylon 66 fabrics using 3 % Imperon Brilliant red B, the time of fixation is 2 min

It is clear from Figs. 7-9 that the highest colour strength values were obtained in case of using polyurethane acrylate based on GE-co-Pas a binder in printing paste while lower values were obtained upon using Ebecryl 2002 in case of screen printed viscose fabrics and in case of using PUA based on PEG2000. The K/S values were better than the values obtained in case of using PUA based on PEG1000 + PEG2000, in case of screen printed viscose and nylon 66 but the inverse was true in case of screen printed wool fabrics. For example, the K/S values of screen printed viscose, wool and nylon 66 fabrics fixed at temperature 16 ºC were 0.64, 4.23, 0.79, 11.42, 1.96, 0.93, 1.84, 6.8 and 2.65, 4.45, 2.5, 8.89 by using Ebecryl 2002, PUA based on PEG2000, PUA based on PEG1000 + PEG2000, PUA based on GE-co-P as a binder in printing paste containing 3 % Imperon red B, respectively. The highest values of K/S in case of using PUA based on GE-co-P may be due to the presence of free hydroxyl besides the unsaturation site in the chemical composition of this type of binder, which leads to increase in the fixation of the pigment dye through either the hydrogen bond which can happen between this binder and the fabrics or cross-linking of the binder. This cross-linkage is essential for physical adhesion of the binder to the textile fiber and to give the pigment print optimum fastness properties.

Effect of type of fabric used: The effect of increasing the fixation temperature on the K/S of screen printed fabrics upon using Ebecryl 2002, PUA based on PEG2000, PUA based on PEG1000 + PEG2000 and PUA based on GE-co-Pas a binder in printing paste containing 3 % Imperon Brilliant red B, the time of fixation of 2 min are represented by Figs. 10-13, respectively. It is clear from Figs. 10 and 13, in case of used Ebecryl 2002 and PUA based on GE-co-P the highest colour strength is obtained at fixation temperature 16 ºC, while in case of used PUA based on PEG2000 as shown in Fig. 11 the highest colour strength is obtained at fixation temperature 18 ºC. In case of used PUA based on PEG1000 + PEG2000 the highest colour strength is obtained at fixation temperature 19 ºC as shown in Fig. 12, this is true irrespective of the type of fabric used.

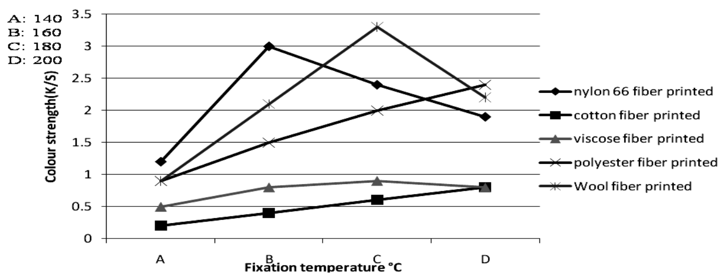

Fig. 10. Effect of the fixation temperature on the colour strength of screen printed fabrics using Ebecryl 2002 as a binder on using 3 % Imperon Brilliant red B, the time of fixation is 2 min

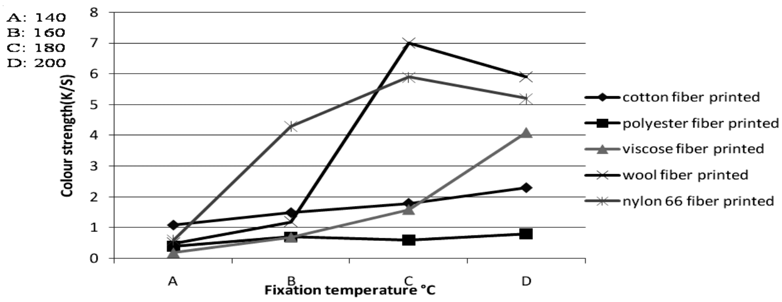

Fig. 11. Effect of the fixation temperature on the colour strength of screen printed fabrics using polyurethane acrylate based on poly-ethylene glycol 2000 as a binder on using 3 % Imperon Brilliant red B, the time of fixation is 2 min

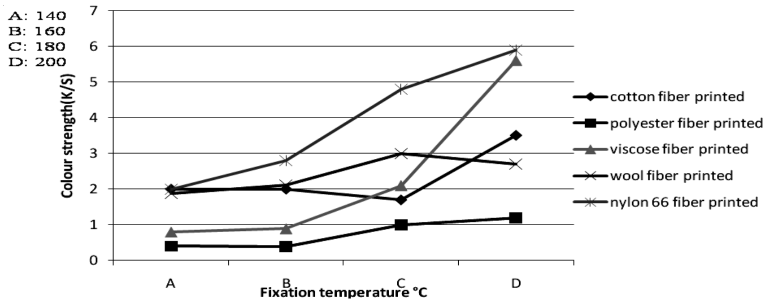

Fig. 12. Effect of the fixation temperature on the colour strength of screen printed fabrics using polyurethane acrylate based on poly-ethylene glycol 1000 C 2000 as a Binder on using 3 % Imperon Brilliant red B, the time of fixation is 2 min

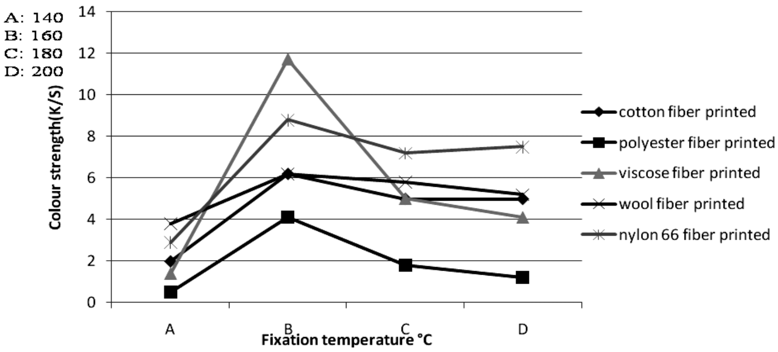

Fig. 13. Effect of the fixation temperature on the colour strength of screen printed fabrics using polyurethane acrylate based on glycerol ethoxylate-co-propoxylate as a binder on using 3 % Imperon Brilliant red B, the time of fixation is 2 min

It is also clear from Fig. 10 that the highest colour strength value was obtained upon using Ebecryl 2002 in case of screen printed nylon 66, wool and polyester, while the lowest K/S value was obtained in case of screen printed cotton and viscose. But in case of using PUA based on PEG2000, PUA based on PEG1000 + PEG2000 and PUA based on GE-co-Pas shown in Figs. 11-13, respectively. The highest colour strength value was obtained in case of screen printed viscose, nylon, cotton and wool while the lowest K/S value was obtained in case of screen printed polyester fabric. This may be due to the difference in the chemical structure and the number of the unsaturated site in each binder used in prepared printing paste.

Fastness properties: Tables 1and 2 show the colour strength and overall fastness properties of screen printed natural and synthetic fabrics using prepared polyurethane acrylate based on either polyethylene glycol or glycerol ethoxylate-co-propoxylate and/or Ebecryl 2002 as a thermal curable binder used in prepared printing paste containing 3% Imperon Brilliant red B.

TABLE-1
COLOUR STRENGTH AND OVERALL FASTNESS PROPERTIES OF SCREEN PRINTED NATURAL AND MAN-MADE FABRICS USING PREPARED POLYURETHANE ACRYLATE BASED ON EITHER POLYETHYLENE GLYCOL OR GLYCEROL ETHOXYLATE-co-PROPOXYLATE AND/OR EBECRYL 2002 AS THERMAL CURABLE BINDERS IN PRINTING PASTE USING 3 % IMPERON BRILLIANT RED B (The time of fixation is 2 min)

Binder user	Type of fabric	colour strength	Rubbing fastness		Washing fastness			Perspiration fastness					
								Acidic			Alkaline		
			Dry	Wet	Staining		Alt.	Staining		Alt.	Staining		Alt.
					Cotton	Wool		Cotton	Wool		Cotton	Wool	
Ebecryl 2002a	Cotton	0.31	4	4	3	4	2	4	4	3	4	4	3
PUA based on PEG2000	Cotton	2.32	4-5	3	4	4	4	5	5	5	5	5	5
PUA based on PEG1000 + PEG2000	Cotton	1.85	3-4	3	4	4	4	5	5	5	5	5	5
PUA based on GE-co-Pa	Cotton	6.83	3-4	3-4	3-4	4-5	4	5	5	5	5	5	5
Ebecryl 2002	Viscose	0.64	3-4	4	3	4	2	4	4	3	4	4	3
PUA based on PEG2000	Viscose	7.32	3-4	3	3	4	3	5	5	5	5	5	5
PUA based on PEG1000 + PEG2000	Viscose	5.51	3-4	3	4	4	3	5	5	5	5	5	5
PUA based on GE-co-Pa	Viscose	11.42	3-4	3	4-5	5	5	5	5	5	5	5	5
Ebecryl 2002	Wool	1.96	2-3	3	4	4	3	4	4	4	4	4	4
PUA based on PEG2000	Wool	2.06	2-3	3	4	4	3	4	4	4	4	4	4
PUA based on PEG1000 + PEG2000	Wool	2.91	3	3	4	4	3	4	4	4	4	4	4
PUA based on GE-co-Pa	Wool	6.8	3-4	3-4	5	5	5	4	5	5	4	5	5

The washing fastness in case of cotton and viscose is at 60 ºC, but in case of wool at 40 ºC. All samples showed soft handling.
Alt. Z alteration, a Fixation temperature at 160 ºC, b Fixation temperature at 180 ºC, c Fixation temperature at 190 ºC.

TABLE-2
COLOUR STRENGTH AND OVERALL FASTNESS PROPERTIES OF SCREEN PRINTED SYNTHETIC FABRICS USING PREPARED POLYURETHANE ACRYLATE BASED ON EITHER POLYETHYLENE GLYCOL OR GLYCEROL ETHOXYLATE-co-PROPOXYLATE AND/OR EBECRYL 2002 AS A THERMAL CURABLE BINDERS IN PRINTING PASTE USING 3 % IMPERON BRILLIANT RED B (The time of fixation is 2 min)

Binder user	Type of fabric	Colour strength	Rubbing fastness		Washing fastness			Perspiration fastness					
								Acidic			Alkaline		
					Staining			Staining			Staining		
			Dry	Wet	Cotton	Wool	Alt.	Nylon 66	Wool	Alt.	Nylon 66	Wool	Alt.
Ebecryl 2002a	Nylon 66	2.65	4	3-4	3	4	2	3-4	4	3	3-4	4	4
PUA based on PEG2000		6.18	4-5	3-4	4	4	3	3-4	4	4	4	4	5
PUA based on PEG1000 + PEG2000		5.72	4	3	4	4	3	4	4-5	5	5	4-5	5
PUA based on GE-co-Pa		8.89	3-4	3	3-4	4-5	4	5	5	5	5	5	5
								Polyester	wool		Polyester	wool	
Ebecryl 2002	Polyester	1.38	3-4	3-4	3	4	2	4	4	4	4	4	4
PUA based on PEG2000		1.11	3-4	3-4	3-4	4	2	4	5	4	4	4	4
PUA based on PEG1000 + PEG2000		1.37	3-4	3	4	4	3	4-5	5	4-5	4-5	4	4
PUA based on GE-co-Pa		4.73	3-4	3	4	4-5	5	5	5	5	5	5	5

The washing fastness at 40 ºC. All samples showed soft handling. Alt. Z Alteration.
a Fixation temperature at 160 ºC.
b Fixation temperature at 180 ºC.
c Fixation temperature at 190 ºC.

It is clear from the data in Tables 1 and 2 that the K/S and overall fastness properties not only depend on the type of binder used in printing paste but also on the type of textile fabric printed. The highest colour strength for all the types of printed fabric was obtained upon using PUA based on GE-co-P as a binder in printing paste and the fixation temperature was 16 ºC for 2 min and the lowest colour strength in case of cotton and viscose printed fabrics upon using Ebecryl 2002 and the change in colour due to washing ranged from poor to good for all printed fabrics. The rubbing, washing and perspiration fastness ranged from good to excellent in case of using prepared binder. This was true irrespective of the nature of the binder used and/or the type of fabric printed.

Conclusion

The present results show that some novel prepared aqueous oligomers (binder)of polyurethane acrylate based on either polyethylene glycol or glycerol ethoxylate-co-propoxylate having zero volatile organic compounds can be used safely for preparing printing paste for screen printing of all types of textile fabrics using pigment dyes. The highest K/S is obtained and the fastness properties range between good and excellent for samples printed using polyurethane acrylate based on glycerol ethoxylate-co-propoxylate, this is true irrespective of the type of printed fabric. The lowest K/S is obtained in case of using Ebecryl 2002 as a commercial binder. The binder of PUA based on PEG2000 gives K/S better than the binder of PUA based on PEG1000+2000 for all the types of printed fabrics unless in case of printed wool, the inverse is true. The fastness properties of goods printed with this system were satisfactory and the hand of printed goods was soft.

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